DETERMINANTS OF TIMING PERFORMANCE ON THE PEAK PROCEDURE

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Abstract

The performance of brown shaver hens *gallus gallus domesticus*, was investigated using a peak procedure as a method to examine the timing abilities of an animal. Peak procedure involves using a combination of peak interval and fixed interval trials, where the peak intervals are four to 10 times long than the FI. Responses during the longer PI trials are not reinforced and do not require a response to end the trial. The Peak procedure generates a pattern of responding that increases to a maximum at the time where behaviour is normally reinforced. The research was conducted on six domestic hens, which underwent FI schedule pretraining and then were introduced to peak testing, FI 20-s/PI 200-s, FI 40/PI 400-s and FI 20-s/PI 80-s schedules. The First 3 condition involved FI 20-s PI 200-s and FI 40-s and PI 400-s schedules, with no house light on during the sessions. The distribution showed a peak at or near the expected time to reinforcement, followed by a steady decrease in responding. The extended period of the trials showed a resonances pattern of responding during the remainder of the trial, with some birds showing resurgence. Condition 7 used FI 20 PI 200-s schedules with a houselight turn on for the whole duration. The response rate increased to the highest point at or near the expected time of reinforcement for all birds, followed by a decrease in responding to a minimum of 1 peck per second. The remainder of the trial displayed a resonances pattern of responding, with half the birds showing resurgences. Condition 8 used FI 20-s PI 200-s schedules with a houselight on during the trial and ITI and off during reinforcement. Patterns of responding were similar to what was seen in the previous conditions. The

final condition used FI 20-s PI 80-s schedules with a houselight on during the trial and ITI and off during reinforcement. Responding was similar to the previous conditions with an increase in responding reaching a maximum at or near the expected time to reinforcement and a decrease followed by a resonances pattern of responding for the duration of the trial.

Acknowledgements

I would firstly like to thank Dr Lewis Bizo for support and guidance throughout this project and his ability to keep me on task for the majority of the time. I would also like to thank Professor Mary Foster for her feedback and editorial assistance towards to end of the project. I wish to thank my fellow students and staff at Dairy No.3 for you assistance with running the experiments throughout this year. A big thank you Jenny Chandler for all your help. I would also like to thank my dad for the endless support he has shown throughout the years and of course the financial assistance. I wish to thank my partner Ashleigh for her willingness and patients to listen to me about my hen stories.

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Animals need to store information about important events both in terms of space and time in their natural environments. Changes within an animal's environment provide cues for various phenomena such as the availability of food, the presences of predators, shelter, and mates. The ability to anticipate such things will increase chances the animals will survive. The ability of animals to time is an area that has been widely researched; researchers have focused on the relationship between time and change, focusing on cyclical change, duration of events and order of events (Roitblat, 1987). Timing is defined as the ability to detect the duration between successive events (Higa & Staddon, 1997).

Fixed-Interval Schedules

One way in which researchers have been able to study the ability of animals to time is by examining performance on Fixed Interval (FI) schedules of reinforcement. An FI is defined as when a fixed interval of time has elapsed since the presentation of a stimulus then a response will be followed by reinforcement (Dews, 1970). The changing of the parameters of the FI has very little effect on the general shape of the curve as seen in Figure 1, for instance changing from an FI 20 s to an FI 40 s does not greatly affect the shape of the curve (Dews, 1970). Figure 1 shows that when relative rate of responding is plotted as a function of relative time, the functions for different FI duration sit on top of each other. This characteristic of timing performance has been called superposition, and results from the scalar property of timing (e.g., Gibbon, 1977). One of the characteristic of the FI schedule is a period without responses known as the post-reinforcement pause (PRP), which is the time after

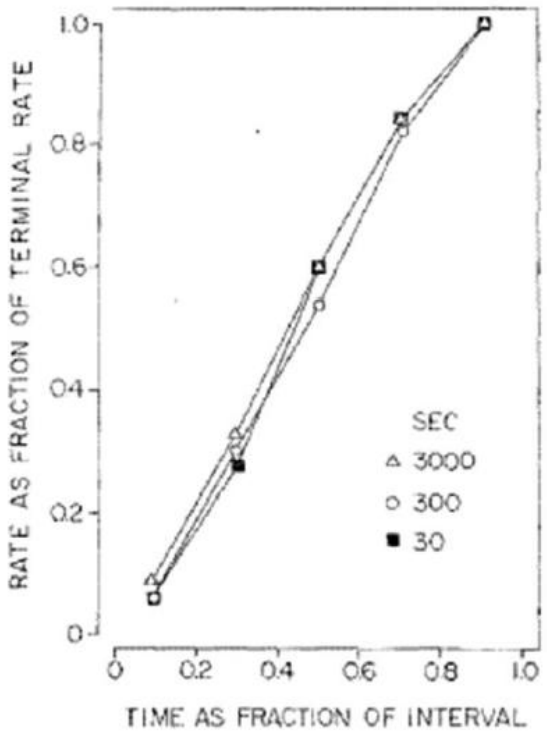


Figure 1: Response rate plotted as a function of time as a fraction of the fixed-interval for fixed intervals of 30, 300 and 3000-s. From "The Theory of Fixed-Interval Responding" by P. Dews (1970), in W.N. Schoenfeld (Eds.), The Theory of Reinforcement Schedules

reinforcement until the first response (Fry, Kelleher & Cook, 1960). The PRP is followed by an increase in response rates to a peak at the end of the FI. This pattern of responding is known as an FI scallop (Dews, 1970). The pattern displayed in Figure 2 shows an FI scallop on a FI 30-s schedule, and responding shows a low rate of responding for the first 15 seconds of the trial, and an increase in responding from 16 seconds though to the time of reinforcement at 30 seconds.

Peak Procedure

In the 1970's Catania devised a method to study the ability of animals to time the point at which reinforcement was available on an FI schedule. On singe key schedules of reinforcement such as an FI schedule, it is possible that animals are not attending to the temporal properties of the schedule at all. They might simple be responding at an increasing rate until a reinforcer is delivered, which would determine the function at the end of the FI. The peak procedure developed by Catania (1970) involved two types of trials; on FI trials responses were reinforced, and extinction trials that were longer than the FI trials and where responses were not reinforced. These two trial types were randomly interspersed in an experimental session with an 80% reinforced trials and 20% extinction trials. These longer trials allowed the animal to respond past the FI duration and if the animal had simply been responding faster until they were reinforced their response rates would have kept increasing beyond the time at which they would normally have been reinforced. During the reinforced trials responding increases to the highest rate of responding at or around the time of reinforcement. During the extinction trials responding is similar

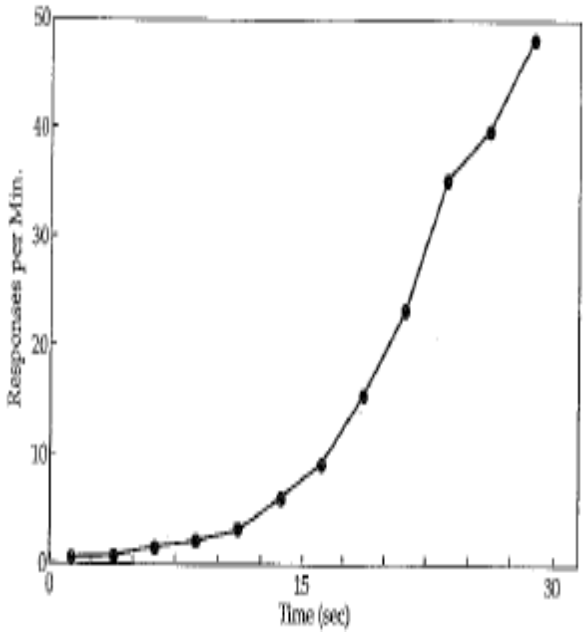


Figure 2: Increase in rate of responding over a 30 s period. Scallop pattern of responding on a FI-30s schedule. From "Timing" by S. Roberts (1998), in Principles of Animal Cognition (pp 249). Boston: McGraw- Hill

to that on reinforced trial with responding being at its highest at or near the time of reinforcement; for the remainder of the trial there is typically a steady decrease in responding followed by some resurgence toward the end of the trial. Kirkpatrick et al., however, found that in certain FI PI trials a double peak was expressed. Figure 3 illustrates the typical pattern of behaviour from a peak procedure experiment. Since the procedure was first described by Catania (1970), the peak procedure has become a popular method for studying temporal control of operant behaviour, and the common finding is that there is an increase in responding until the time of responding on the extinction trials, followed by a decrease in responding (Church, Miller, Meck & Gibbon, 1991). Kirkpatrick-Steger, Mill, Betti and Wasserman, (1996) stated that there was still very little known about the origins of temporal control on the peak procedure. Kirkpatrick et al., wanted to investigate the responding observed on the peak procedure after extended training, and if the distribution of responding would be affected by prolonged exposure on the peak procedure.

The research involved five experiments involving pigeons that were naïve to the peak procedure. Experiment 1 involved dividing the subjects into two groups, one would receive reinforcement on the PI and the other did not. The experiment first involved pigeons being training on a FI 30-s schedule until a scallop of the response rate developed. The pigeons were introduced to PI trials, which were four times longer than the FI 30 s. They were then assigned to two groups; the first group did not receive reinforcement after PI 120-s trials and the second group did.

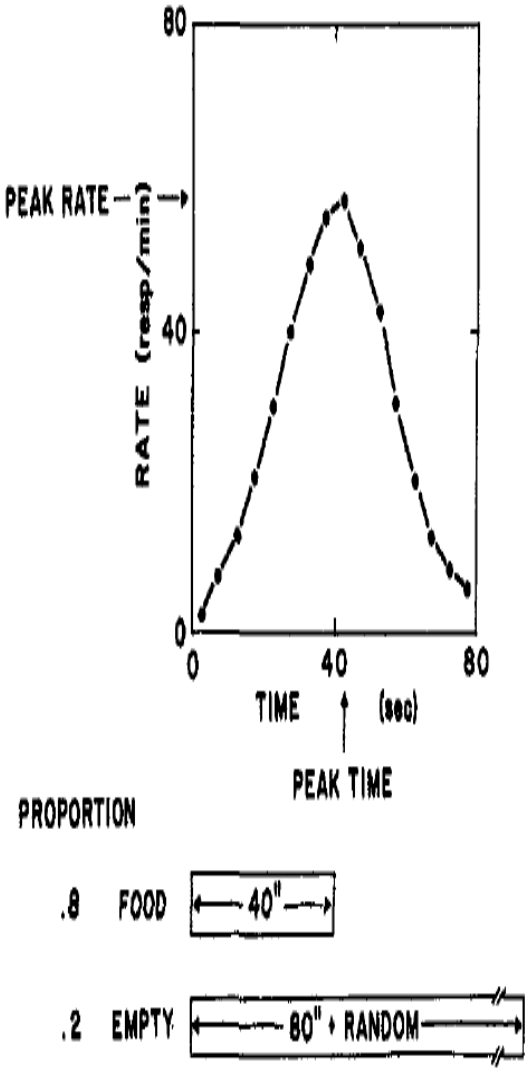


Figure 3: The basic elements of the peak procedure and performance. From “Isolation of an Internal Clock”, by S. Roberts, (1981), *in Journal of Experimental Psychology: Animal Behavior Processes*, 7(3), pp. 259.

The results show that the group that did not receive reinforcement at the end of the PI trials developed a double peak in the response rate distribution, and the other group just a single peak, these results are displayed in Figure 4. The second experiment involved using three different groups of subjects and examining the response rate per minute. The groups were: FI 15-s/PI 120-s, FI 30-s/PI 120-s and FI 30-s/PI 240-s. Responding during the PI trials were not reinforced and PIs values were either 4 or 8 times as long as the FI trials. The results from this experiment showed that a double peak developed only in the FI 30-s/PI 120- s which had a PI 4 times the length of the FI.

Based on the results from the previous experiment Kirkpatrick et al., were interested in whether the ratio between FI and PI was key to developing the double peak or whether it was the use of a 15-s time interval. Therefore the 15-s time intervals were removed and the 1:4 ratios were retained. The results show that the double peak occurred with FI 38-s PI 152-s and it was concluded that the FI did not have to the divisible by 15 s and it was the ratio that was important in developing the second peak.

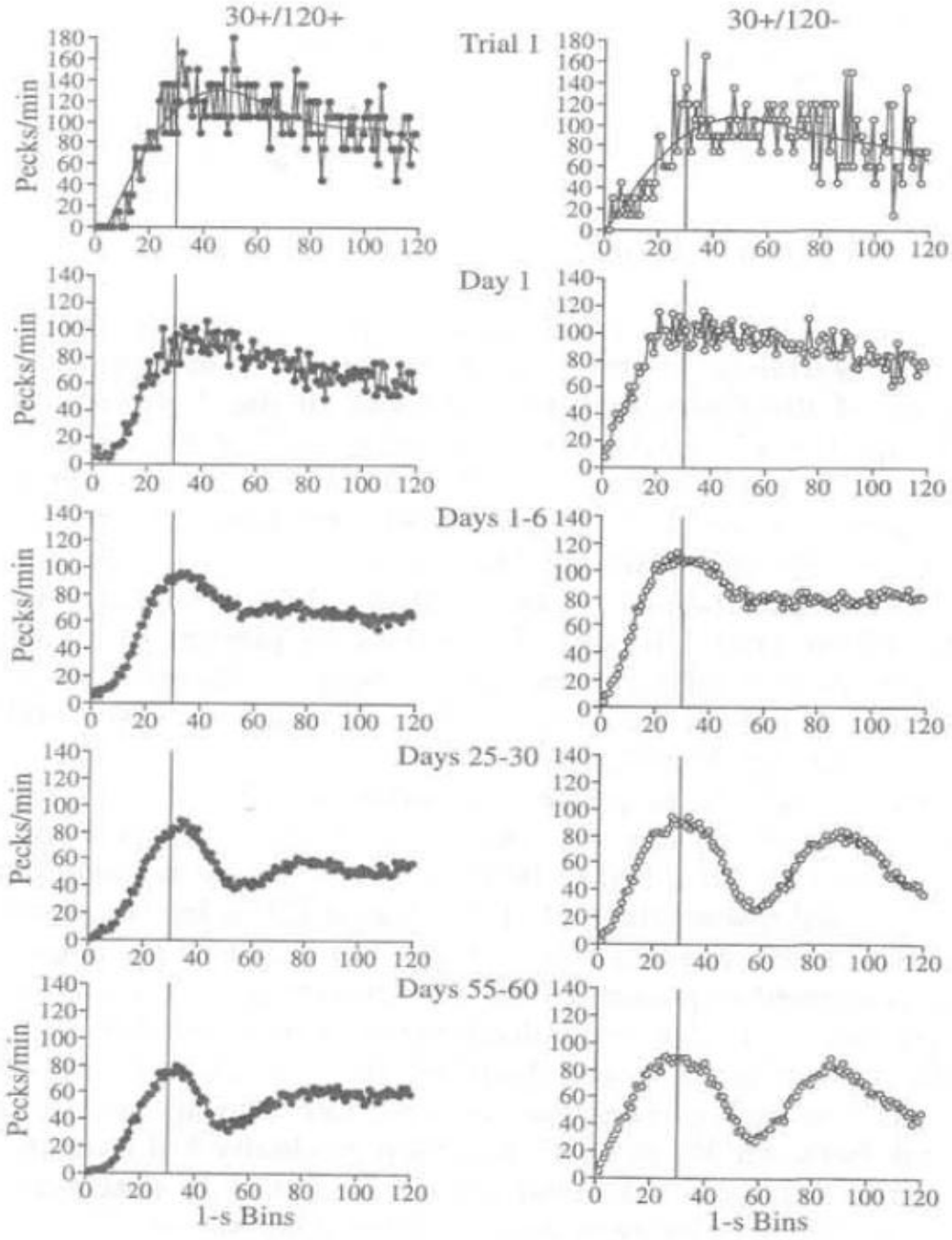


Figure 4: Response rate in 1-s bins for 30-s FI and 120-s PI testing. From "Cyclic Responding by pigeons on the peak timing procedure" , by Kirkpatrick, Miller, Betti & Wasserman (1996), In Journal of Experimental Psychology, 22(4), pp 450

A replication of Kirkpatrick et al. (1996) research was conducted by Sanabria and Killeen (2007) who aimed to develop general models of PI performance. Sanabria and Killeen (2007) suggest that a limitation of the Kirkpatrick et al. (1996) study was related to the illuminated chamber. Killeen and Sanabria therefore tried to minimise the effect of illumination by using a darkened chamber for pigeon and tones for rats. There were two experiments conducted with the first using rats and the second with pigeons. The first experiment used a combination of seven different FI and PI trials, with the probe trial being 4 times as long at the lowest point and 16 times as long at the highest. The target FI was 15, 30 or 60 s and the associated PIs were 60, 120 and 240 s, respectively. The results from this experiment showed that data obtained during the peak procedures were well described by Gaussian distributions. The second Gaussian distribution, centred on next reinforcement, showed the responding was controlled by the next reinforcement, the reinforcer in the current trial and following trial. Results indicated that tone offset after a probe trials also produced increased behaviour during the ITI.

Internal Clock

The distribution of response rates on timing tasks leads us to think that animals have an internal clock. The internal clock model has previously been described by others (Church, 1984; Gibbon & Church 1984; Gibbon, Church & Meck, 1984). Internal clock models consist of four major components; a clock, working memory, reference memory and a comparator, see Figure 4. A clock as shown in Figure 4 might comprise of three components: a pacemaker, a switch and an accumulator. The

pacemaker is an internal mechanism that emits a pulse at a regular rate (Church, 1984). The switch is described as "on" when the pulses are directed to the accumulator, in order for an animal to time an event (Church, 1984). The three components work together to produce a "value". The value from the accumulator can then be transferred to the working memory or to the reference memory (Church, 1984). The working memory is a short term memory where information about the current reinforcement is stored (Church, 1984). If the pulses from the working memory are similar to a previous experience that resulted in successful reinforcement, the information is stored in the reference memory (Church, 1984). The comparator controls the response, if the response ends in reinforcement the number of pulses will be stored in the reference memory (Church, 1984).

The relationship between the internal clock model and peak procedure could be observed by responding on a FI trial that increased at about the expected time of reinforcement. The subject would be using the clock to time when reinforcement is likely to occur, as the number of pulses increased during the duration of the FI the likelihood of responding would increase the closer this number got to a reference memory value. During the PI trials, the process would be repeated and responding would be expected to increase around the time of expected reinforcement. When reinforcement did not occur it would be expected the responding would then decrease (Roberts & Church, 1978)

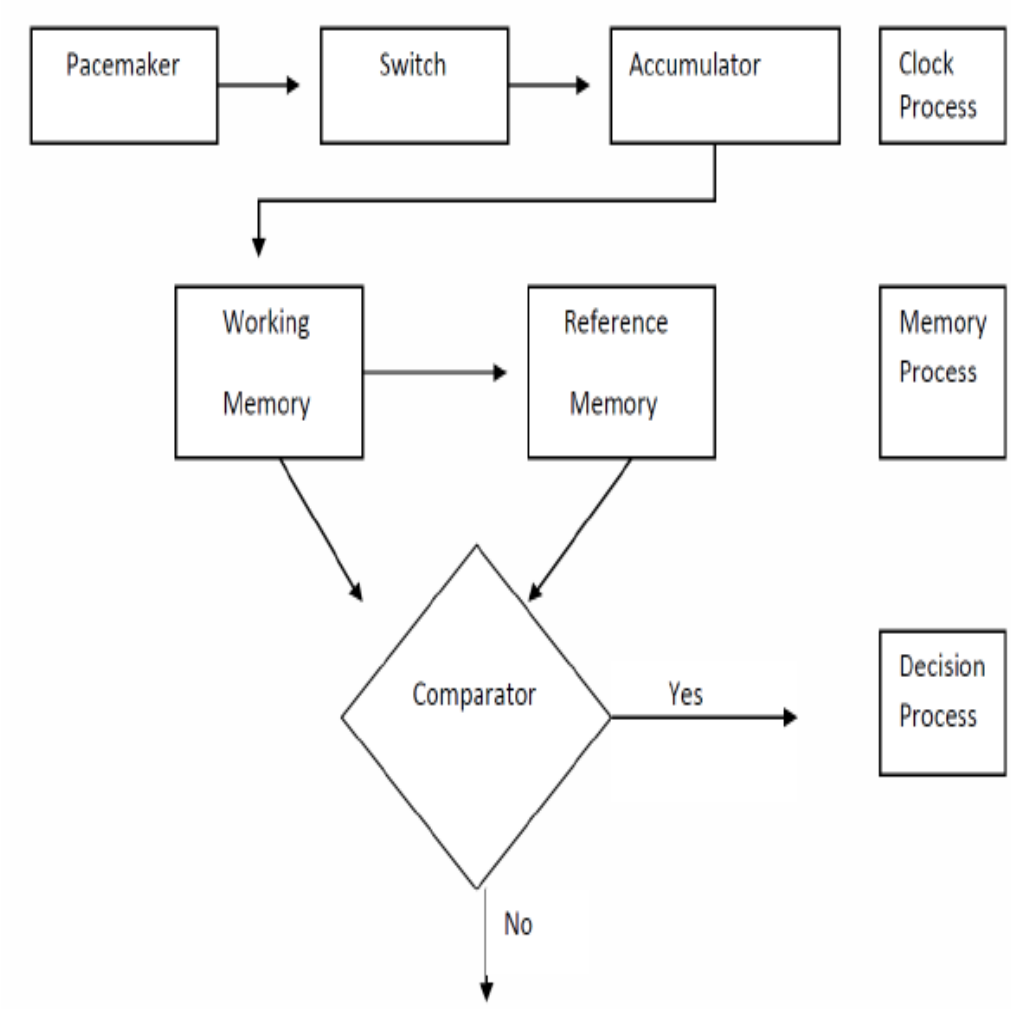


Figure 5: The scalar property of timing processing model devised by Gibbon and Church (1984). The model encounters three processes including clock, memory and decision making. from “Sources of Variance in an Information Processing Theory of Timing,” by J. Gibbon.

When reinforcement does not occur some theorists suggests that the clock does stop and not continue running. Roberts, Cheng and Cohen (1989) have suggested that the clock stops and is reset while other researchers have suggested that the clock does not stop (Cabeza de Vaca et al. 1994; Killeen & Fetterman, 1988; Roberts & Church, 1978). Roberts (1981) suggests that the clock does not reset during breaks, but that the clock stops and starts accumulating for the post-break time to the pre-break time.

Roberts and Church (1978) used three experiments in order to show the amount of control of the clock in rats. The first experiment investigated stopping the clock using a FI procedure. The experiment involved training on a FI 60-s schedule until the responding to when the food was primed. The aim of this experiment was to find out what the clocks did during the breaks. The results show that neither group could stop the clock consistently; results show a large range in the rate of responding, it was concluded overall that the rats' clock did stop during the breaks. Similar results were found by Dews (1962) with pigeons. These authors argued that the animals' clock did stop during breaks. Roberts and Church's (1978) second experiment looked at the effect of choice, using a long (12 s) and short FI duration (less than 12 s) that had different corresponding break times. The results showed that the long breaks were similar to those in in first experiment, and it was concluded that the clock stops during the break time, as there was a decrease in responding during the breaks. The final experiment investigated the FI procedure, by using a combination of FI 30-s and FI 60-s trials; both with

different signals. The results showed that the same clock timed the two different signals, time is absolute and the clock appears to counts up.

Furthermore Roberts (1981) extended the research conducted by Catania with the major aims being to show that peak rate can change without altering peak time; peak time can change without changing the peak rate and to show the effect of changing peak time, peak rate and response-rate function. The results of Experiment 1 showed time discrimination through the change in response rate with a change in time. There was a difference between signal and response rate. Figure 6 shows there was a difference in response rate between the two signals and therefore changing the food changed the peak time.

Experiment 2 aimed to measure the effect of a range of breaks early in the trial. The breaks were dark periods and trials were conducted with a light on. The results from this experiment were that the break increased peak time, but did not increase peak rate. The peak time was dependent on the length of the break. Roberts concluded that the blackouts stop the internal clock. Similar finding were noted by Roberts and Church (1978). Roberts (1981) concluded that reinforcement resets the internal clock to some extent and when the reinforcement was omitted from trials that normally would have reinforced responses, the clock resets. Roberts has also suggested that the clock "times up" meaning that the internal clock starts at the same place at the 20 and 40 s signal.

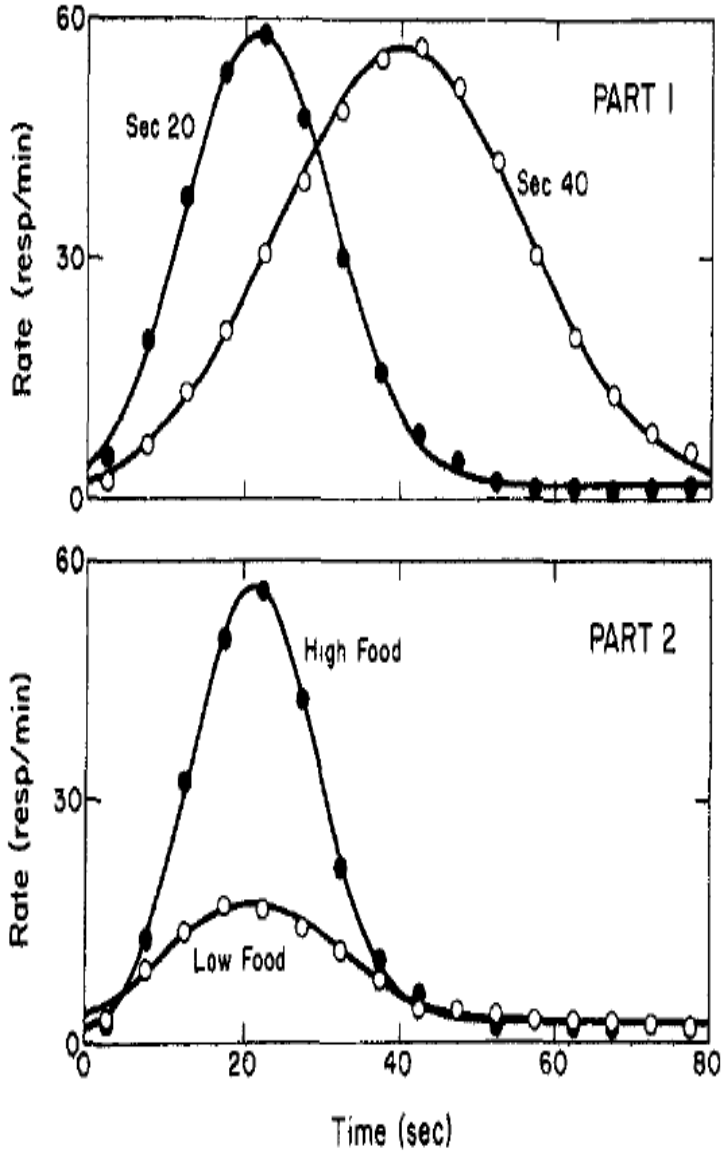


Figure 6: Mean response rate as a function of time. From "Isolation of an Internal Clock", by S. Roberts, (1981), in *Journal of Experimental Psychology: Animal Behavior Processes*, 7(3), pp. 245.

With the difference in peak time between 20 and 40 s being due to difference in criterion time. This experiment also provided more evidence that the peak rate and peak time are independent measures. If the clock has the ability to reset and start from zero this could explain the double peak that was shown in Figure 4.

There are three main theories of timing that make use of "pacemaker-counter" type models: Scalar Expectancy theory (SET) (Gibbons, 1977; Gibbons & Church, 1984), the Behavioural Theory of Timing (BeT) (Killeen & Fetterman, 1988), and Learning to Time (LeT) (Machado, 1997). The three models are very different in the way they describe and measure timing performance. SET is a cognitive approach to timing and suggests that various information-processing devices explain the learned behaviour (Gibbon, 1977; Gibbon & Church, 1984). SET is a theory that suggests animals are able to create an expectant time to reinforcement (Gibbon, 1977; Gibbon & Church, 1984). BeT is a theory that proposed that it is an animal's own behaviour that is used to judge time and so the behaviour is used as discriminative stimuli as to the passage of time (Killeen & Fetterman, 1998). LeT, was derived from BeT with linkage between behavioural states and response (Machado, 1997; Machado & Keen, 1999).

The present experiment is a partial replication of Kirkpatrick et al. and investigates performance on the peak procedure and the effect of PI duration on performance. Hens (*Gallus gallus domesticus*) were chosen as experimental subjects, and relatively little is known about their ability to time. Previous master theses (Ji Yoen, K, 2002) and (Lockhart, 2011) have

examined the timing ability of brown shaver hen and brushtail possum respectively. The aim of the present research was to explore the performance and learning of hens on the peak procedure, and to explore factors that may influence the patterns of responding on this procedure. The variables that were manipulated were, the duration of the FI, introduction of a house light and the duration of the PI trials. It was earlier shown by Kirkpatrick-Steger et al., (1996) that a double peak was reported in response rates. Sanabria and Killeen (2007) did not find a double peak in response rates. Similar results to Sanabria and Killeen were shown to by Galtress and Kirkpatrick (2009).

In the present experiment, the end of the PI trials did not give a reinforcer or any other scheduled consequence except the end of the trial and the start of the Intertrial Interval (ITI). The expectation in the present experiment was that if the hens were timing both the delivery of reinforcement on FI trials and the end of the trial, that performance on the PI trials would be characterised by an increase in response rates to a peak at the time the animal would be reinforced had the FI been in effect, followed by a decrease in response rates before response rates then increased a second time toward a second peak at the end of the trial.

Method

Subjects

Six brown shaver hens (G*allus gallus domesticus*) participated in the experiment and were about 1 year and 3 months old at the start of the experiment. The hens were housed individually and had free access to water when they were not in the experimental chamber. The hens were all maintained at 85% +/- 5% of their free feeding body weight. Timed access to wheat was used as the reinforcer during the experimental sessions and commercial laying pellets were provided after each session if needed to maintain the hens' weight, hens were given vitamins and grit weekly. A 12:12 hr light/dark cycle was in effect in the hens' home cage room with lights on at 7 am and off at 7 pm. This research was approved by the Ethics Committee of the University of Waikato prior to the start of the experiment (ECN 825).

Table 1: The subjects' 80% free feed weights and ages at start of experiment.

Subject	Target Weight (Grams)	Age
8.1	1400	1yr 3month
8.2	1640	1yr 3month
8.3	1650	1yr 3month
8.4	1660	1yr 3month
8.5	1660	1yr 3month
8.6	1630	1yr 3month

Apparatus

An experimental chamber with internal dimensions measuring 600-mm long, 480-mm wide 410-mm high was used. The floor was covered with a plastic floor protector and a rubber mat with a total raised height of 11 mm. The Perspex response keys measuring 30 mm in diameter were mounted 340 mm from the bottom of the chamber and 80 mm from the side of the chamber. The centre key could be illuminated with a 1-W light bulb during an experimental session. The force required for a response to be recorded was 0.15 N. An opening in the front panel of chamber measuring 75-mm wide and 120-mm high, provided timed access to the wheat from a hopper; when the hopper was raised it was also illuminated with a 1-W light bulb. A house light bracketed to the top of the chamber was illuminated with a bulb. A Pentium ® 4 C.P.U, 3.00 GHz, computer loaded with Microsoft window XP 2002 and with Med-PC ® versions IV were used to control and record experimental events. The experiments were run via a Med-PC interface and power supply (0-30v 5A)

Procedure:

Training.

At the beginning of the training phase, each hen was placed in the chamber. In the first session, a trial was started when the central key was illuminated. Initially key pecks were reinforced according to a FI 5-s schedule, where the first key peck after 5 s (FI 5-s) resulted in the key light turning off and the food hopper being activated allowing 2.5-s access to food. After the hopper was lowered, there was a 5-s (ITI). The session ended after 3600 s had elapsed or after 50 reinforcers were obtained,

which ever occurred first. For the second session the FI duration was increased from FI 5 s to FI 10 s, and after the third session it was increase to FI 20 s for an additional 30 sessions. Table 2 shows the order of conditions and number of session in each condition.

Peak Procedure

The peak procedure involved FI trials and PI trials. The signal for the start of probe trials remained the same as the FI training and key pecks were recorded over the period of each trial. The end of the FI and PI trials was signalled by the key light turning off. Access to wheat was timed for 2.5 s during the reinforcement. On the non-reinforcement (PI) trials no reinforcement access occurred. The PI trials were 10 times longer than the FI trials. There were a total of 25 trials, consisted of 20 FI trials and 5 PI trials. The order of the FI and PI trials were pseudo-randomly organised so that they could not experience more than 2 PI trials in a row. Sessions ended when there were a total of 25 trials or 3600 s had elapsed, whichever occurred first.

Condition 1 was FI training where hens were trained to respond on an FI 20-s schedule of reinforcement, for a total of 30 sessions. In Condition 2 the hens were exposed to the peak procedure with a FI 20-s and PI 200-s schedules being used with no houselight during the trials or ITI for a total of 40 sessions. Condition 3 was the same as Condition 1 with the exception of the FI being increased from FI 20 s to FI 40 s and this being in place for 30 sessions. Condition 4 was the same as Condition 2 with the exception of an increase in the FI and PI value, from and FI 20 s

to an FI 40-s and PI 200 s to PI 400 s. Conditions 5 and 6 were the same as Condition 1 and 2 with the exception of including 10 training sessions and 20 peak testing sessions. Condition 7 was the same as Conditions 1, 2, 5, and 6 with the only difference being a houselight on during trials and ITI periods. Condition 8 was the same as Condition 7, with the only change being that the houselight was on during the trial, and off during the ITI. Condition 9 was the same as Condition 8, with the only change being a decrease in the PI from a PI 200 s to a PI 80 s.

Table 2: The name of each experimental condition, whether or not a houselight was on or off within each condition and the total number of sessions used in each condition.

Condition Number	Condition	Trial	ITI	Number sessions
1	FI 20-s Training	No houselight	No houselight	30
2	FI 20 s PI200 s	No houselight	No houselight	40
3	FI 40-s Training	No houselight	No houselight	30
4	FI 40 s PI 400 s	No houselight	No houselight	45
5	FI 20-s Training	No houselight	No houselight	10
6	FI 20 s PI 200 s	No houselight	No houselight	20
7	FI 20 s PI 200 s	Houselight	Houselight	20
8	FI 20 s PI 200 s	Houselight	No houselight	20
9	FI 20 s PI 80 s	Houselight	No houselight	20

Results

FI Training

The response rates were calculated in 1-s bins separately for FI and PI trials for individual hens and sessions. Response rates were compared across FI-PI schedules by plotting them as a function of relative time. Relative time was calculated by dividing the each time interval by the maximum amount of time per trial, i.e. 1-s divided by 200-s for a PI 200-s. Additionally, when performance is expressed as relative rates of responding this was achieved by dividing the response rate for the last five days in each time class interval (1-s bins) by the maximum mean response rate for individual schedules and individual animals for the last five days.

The relative rates of responding plotted as a function of time are displayed on Figure 6 averaged for the last five days of FI 20-s training (Condition 1) and FI-40 s training (Condition 3). The rate of responding at the start of the trial was low with a gradual increase in responding; with the highest rate of responding occurring close to the time of reinforcement. Similar patterns of responding to were observed in both FI20 and FI40 training, with an increase in responding occurring close to the expected time of reinforcement.

Peak Testing

Responses rates, plotted as a function of time for each individual bird during Condition 2 (FI20-s/PI200-s) are shown in Figure 8. Each data point is from 1-s bins and they were averaged over the last 5 sessions of the condition. Figure 8 shows that there was an increase in responding from the start of the trial and response rate reached its highest point at about the expected time of

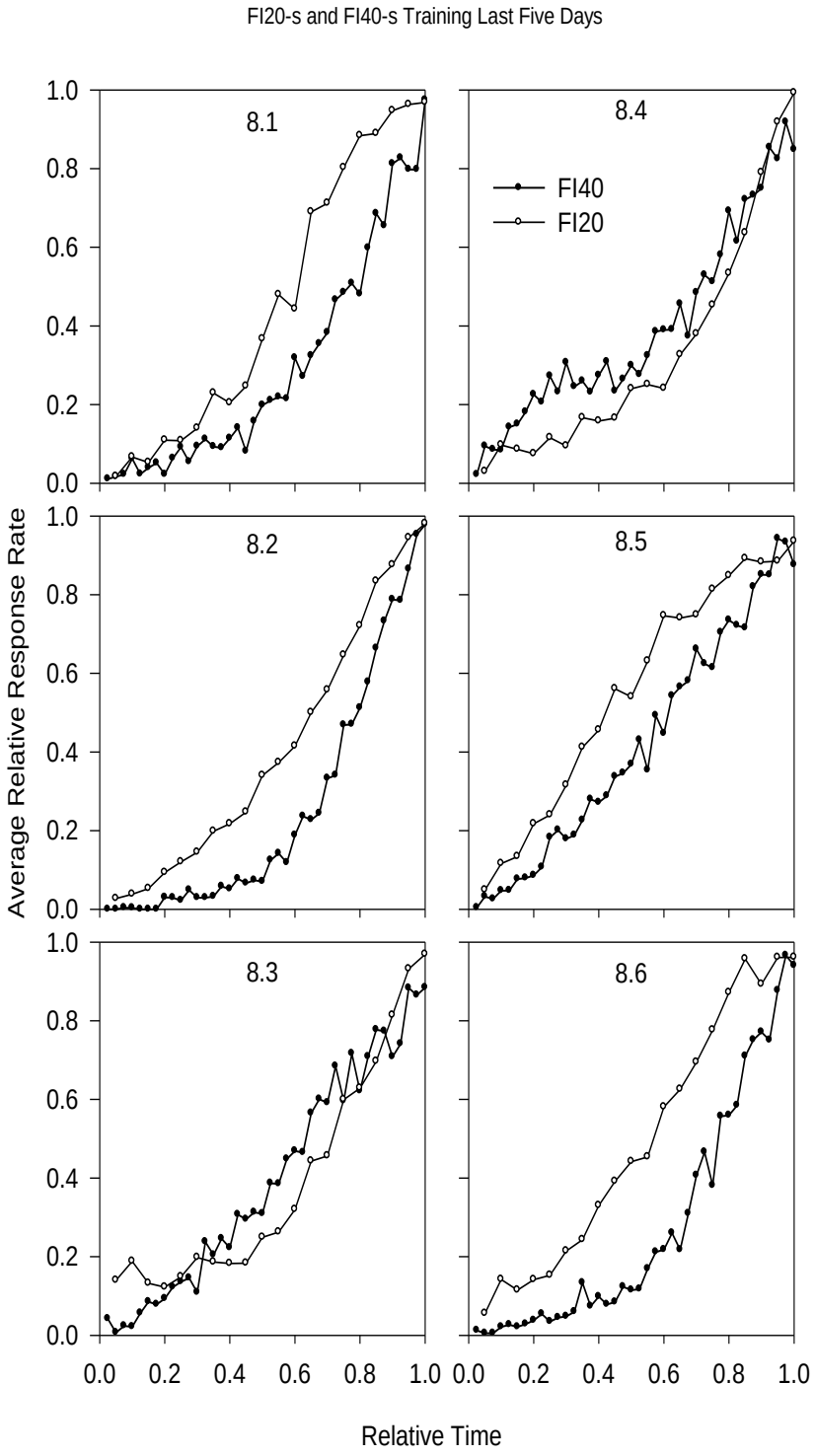


Figure 7: Mean relative rate of responding plotted as a function of relative time for Condition 1(FI 20-s) and Condition 3(FI 40-s) averaged over the last 5days for individual animals.

reinforcement response rate then decreased after the expected time to reinforcement. The pattern of responding after the expected time to reinforcement shown in Figure 8 was that responding continued and did not extinguish during the PI trials across all six birds. None of the hens showed a second peak similar to the initial peak, at the second expected time of reinforcement

Response rate plotted against time for condition 4 (FI 40-s PI 400-s) are shown in Figure 9. The result showed that all bird had a high rate of responding just before the expected time of reinforcement, with the expected time of reinforcement the highest point. This was followed by a decrease in responding. One bird (8.1) shows an oscillation pattern of responding during the remainder of the trial. Three birds (8.2, 8.4 and 8.5) show a constant rate of responding, with no obvious increase or decrease in responding over the two birds. Two birds (8.3 and 8.6) showed some resonance in their response patterns, during the latter part of the PI trial.

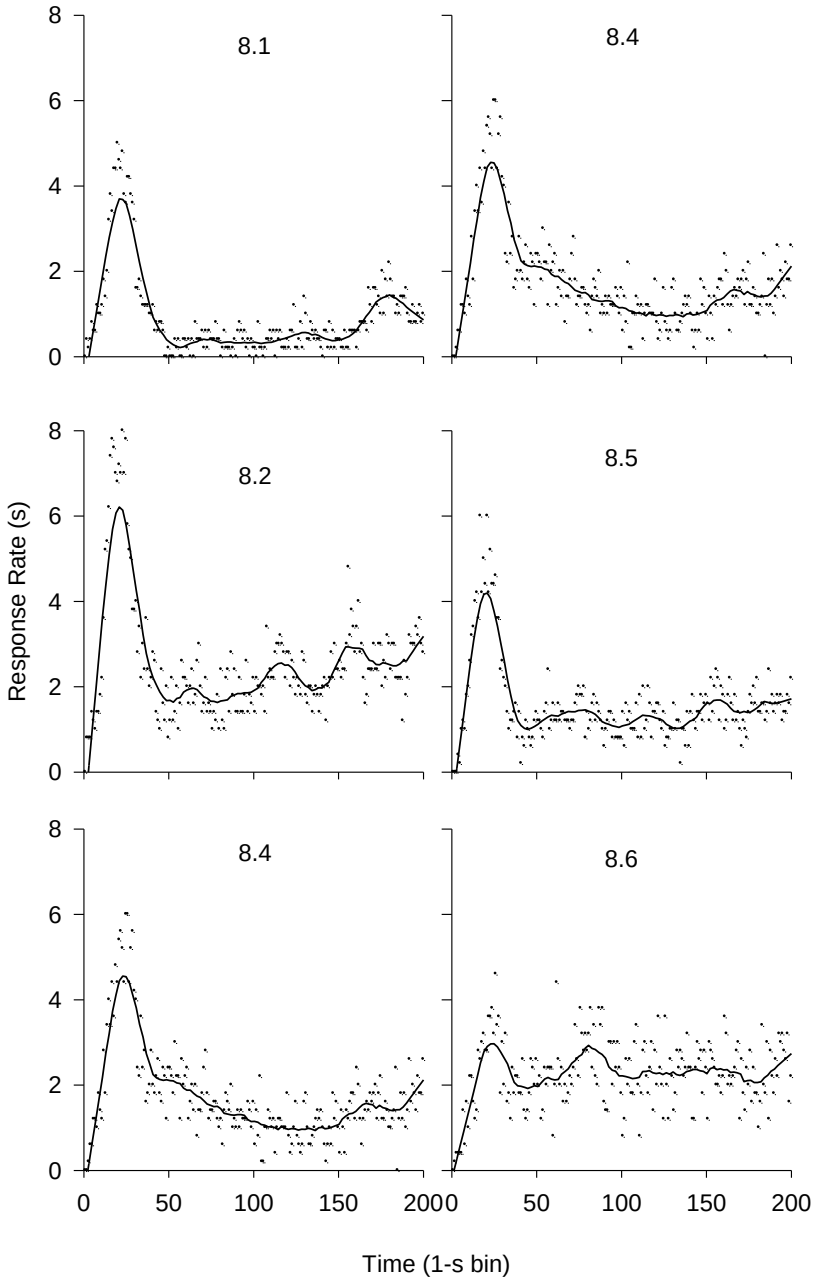


Figure 8: Condition 2 response rate of responding of the last five days plotted as a function of time on a PI 200-s schedules. Mean rate of responding(data points and a negative exponential line)

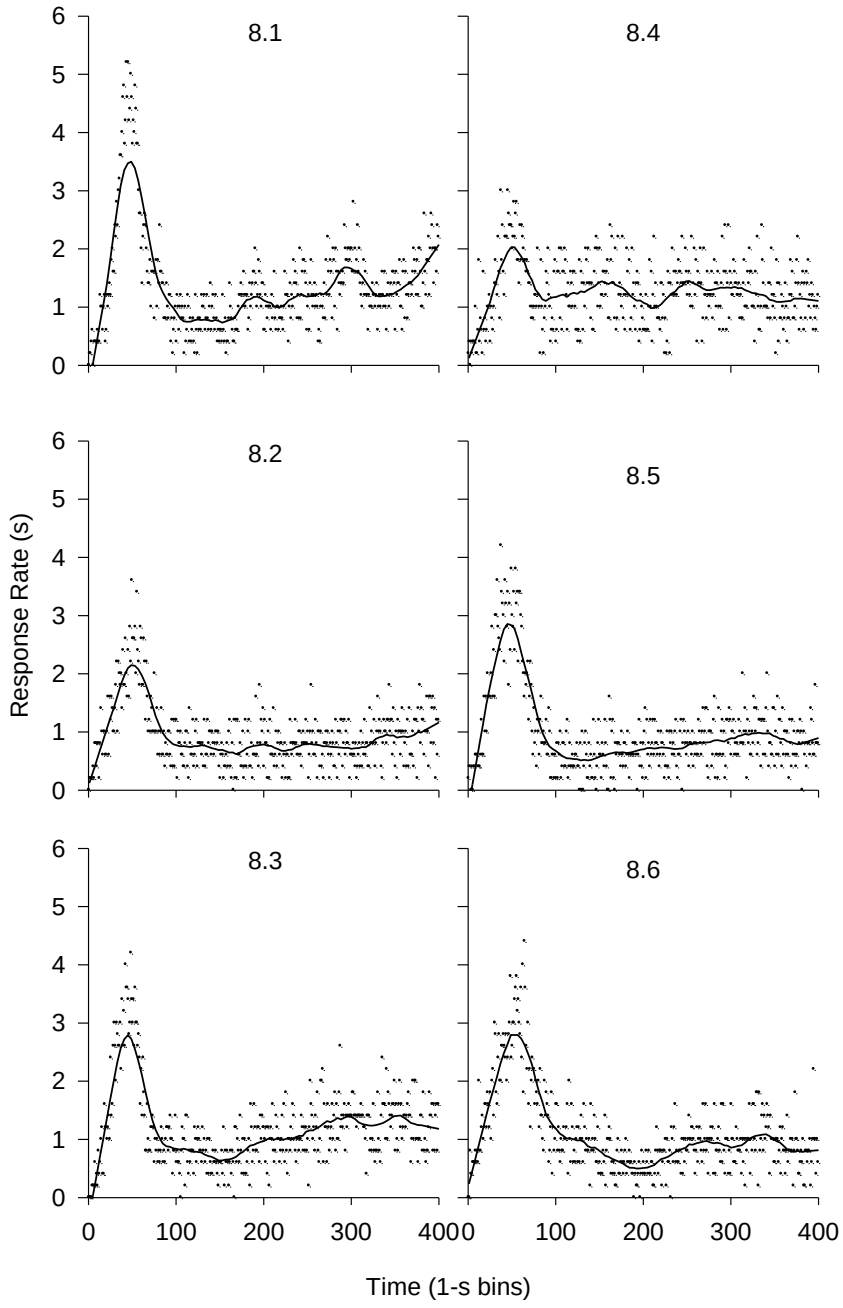


Figure 9: Condition 4 response rate of the last five days plotted as a function of time on a PI 400-s schedules

Response rate, plotted against time for Condition 6 (FI 20-s/ PI 200-s) are shown in Figure 10. Figure 10 shows that there was an initial increase in responding with responding reaching its highest point near the expected time of reinforcement. This was followed by a decrease in responding after the expected time of reinforcement. The responding after the first 40-s of the trials was variable across the subjects. One bird (8.2) showed an oscillation pattern of responding, the remaining birds showed reasonably constant response rates throughout the remainder of trial.

The response rate data for Condition 7 (FI 20-s/PI 200-s) are shown in Figure 11, where there was the inclusion of a house light for the duration of the trials and ITI periods. The results overall show a similar trends to those from Conditions 2, 4 and 6. One bird (8.6) showed a resonance pattern, with a higher second peak than the other birds. Two birds (8.2 and 8.5) showed a low level of responding after the decreased in responding following the expected time to reinforcement. The other three birds (8.1, 8.3 and 8.4) showed that after the initial peak at the expected time to reinforcement, responding continued to occur throughout the session and there was some resonance.

The data for Condition 8 (FI 20-s/PI 200-s) are displayed in Figure 11, where the houselight was on during the trials and off during ITI. Figure 11 shows responding increased until just after the time of expected reinforcement, followed by a decrease in responding by all birds. For all birds responding continued for the duration of the trial and there was very little isolation in the data.

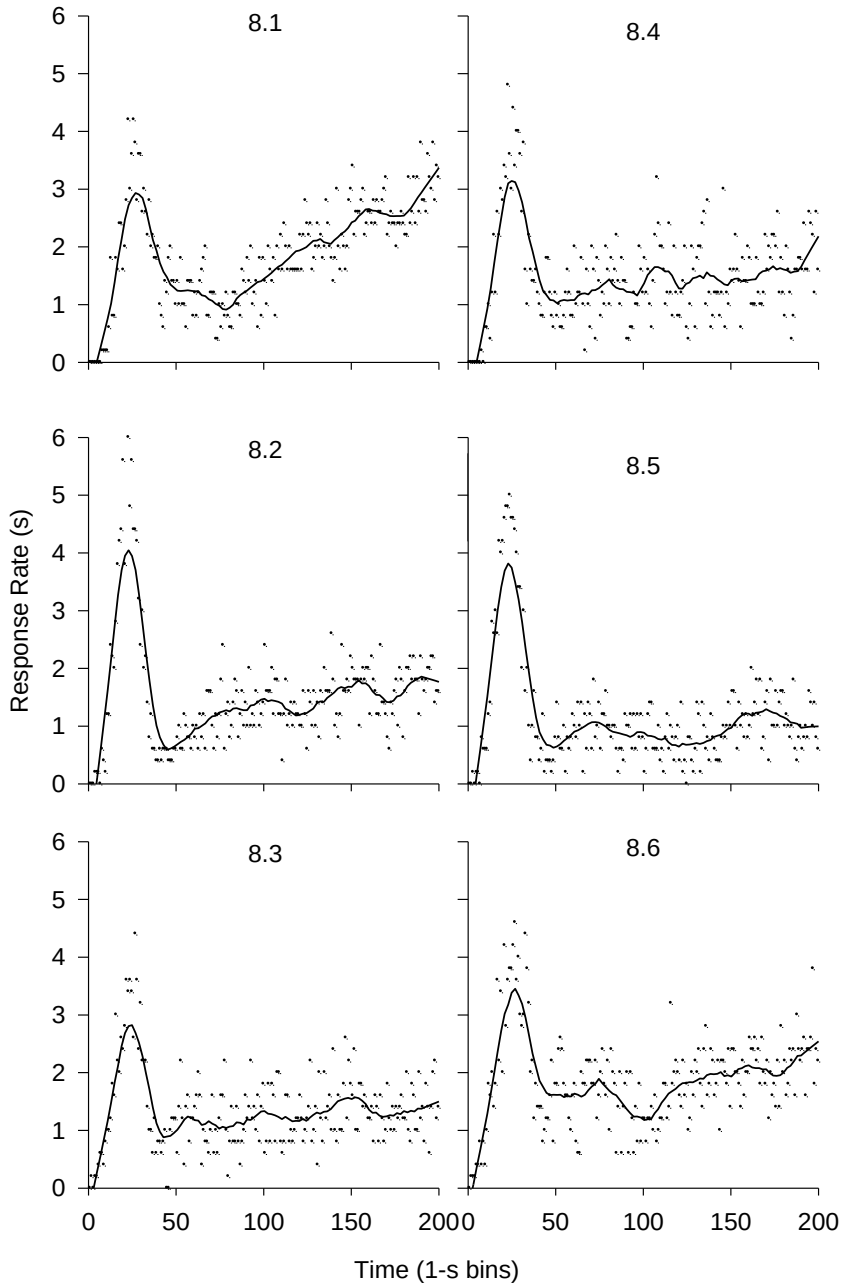


Figure 10 : Condition 6 response rate of responding from the last five days plotted as a function of time on a PI 200-s schedules

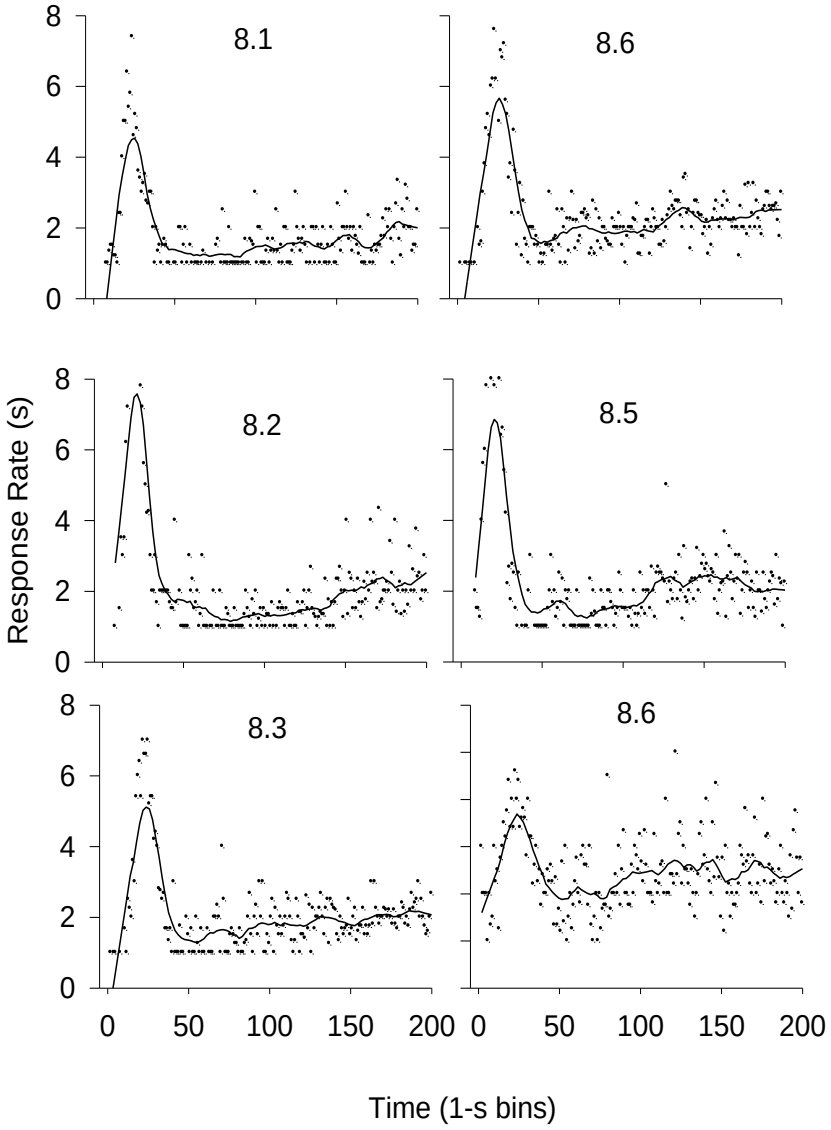


Figure 11: Condition 7 Response rate of the last five days plotted as a function of time on a PI 200-s peak interval trial with a houselight on during trials and ITI periods.

The means and standard deviation of the response distributions were calculated using data from the start of the PI trial to twice the duration of the FI value that was in effect during the condition. The distributions were calculated for the last five days of each condition and individual birds. Weber fractions (or coefficient of variation) were calculated by dividing the standard deviation of the response distributions by their mean response distribution. Condition 2 (FI 40-s PI 400-s no houselight) had the highest overall mean of 46.82-s and Condition 3(FI 20-s PI 200-s no houselight) had the highest mean of the FI 200-s PI 200-s conditions with a mean of 24.42-s. The overall standard deviation was higher in Condition 1 with an average SD of 8.14-s. However, an exception to this was bird 8.6 in Condition 4 which had a SD of 9.93-s. Condition 3 had the lowest SD overall with an average of 8.17-s. The Weber Fraction shown in Table 3 showed that overall Condition 1, 4, 6 showed the highest overall Weber Fractions being 0.35, 0.34 and 0.32. The lowest score was Condition 2 and the average score for the condition was 0.16.

Repeated measures (ANOVA) were conducted on the Weber Fractions. Test of sphericity showed $p < 0.5$, therefore showing significance differences between the variances of the different conditions. Size F is not significant because p >0.05.. The repeated measure ANOVA showed that there is a significant difference between the Weber scores of condition 1 to 6. ANOVA repeated measures were also conducted on the data from the Weber fractions for last five sessions and first 5 sessions for conditions 4, ($F(1, 5) = 6.01$, $p < .05$) Condition 5 and 6 were also compared using a repeated measure ANOVA ($F(1, 5) = 4.96$, $p < 0.05$.) There was a significance difference was found between conditions 4 and 5, and 5 and 6, with $p < 0.05$ in both ANOVAS.

Table 3: Mean and standard deviations for the response distribution for individual birds across all 6 conditions, and Weber's fraction (or coefficient of variation) for individual birds across all 6 conditions for the last 5 days of each condition

Mean (s)

Hens	Cond 1	Cond 2	Cond 3	Cond 4	Cond 5	Cond 6
8.1	25.51	47.05	25.18	25.06	24.60	23.17
8.2	22.23	47.06	23.13	21.80	21.81	22.30
8.3	25.39	45.18	23.76	23.77	24.11	25.66
8.4	23.70	47.66	25.64	26.17	25.84	25.14
8.5	21.53	46.01	23.60	20.41	21.38	21.44
8.6	23.82	47.96	25.18	22.46	24.39	24.11

SD (s)

Hens	Cond 1	Cond 2	Cond 3	Cond 4	Cond 5	Cond 6
8.1	7.86	7.25	5.28	7.86	6.47	6.72
8.2	8.30	7.35	5.00	7.00	5.46	6.34
8.3	7.51	7.13	5.12	7.83	6.39	9.30
8.4	8.36	7.39	5.25	7.79	6.65	6.51
8.5	7.89	7.23	5.07	6.64	5.32	6.41
8.6	8.90	7.44	5.28	9.93	8.53	8.90

Weber Fraction

Hens	Cond 1	Cond 2	Cond 3	Cond 4	Cond 5	Cond 6
8.1	0.349	0.154	0.210	0.313	0.263	0.290
8.2	0.373	0.156	0.216	0.321	0.250	0.299
8.3	0.296	0.158	0.216	0.329	0.265	0.344
8.4	0.353	0.155	0.205	0.297	0.257	0.352
8.5	0.367	0.157	0.215	0.325	0.249	0.259
8.6	0.374	0.155	0.210	0.442	0.350	0.369

Results Summary

The pretraining data for FI 20-s and FI 40-s is shown in Figure 7. A PRP is slightly evident in the data distribution shown on Figure 7, with an increase in

responding towards the end of the time interval. All hens' rates of responding increased to their highest point at or near to the expected time to reinforcement. The data for both training conditions showed similarities to the FI scallop displayed in Figure 2, as the rate of responding was slow at the beginning of the trial with a steady increase in the second half of the trial producing a "concave" pattern of responding.

During the peak procedure hens experienced FI 20-s and FI 40-s intervals, and PI intervals were 10 time longer in the first five peak procedure conditions and four times in the sixth. The first three conditions the hens experiences the FI and PI trials with no houselight and the final three conditions there was a houselight on during differing parts of the trials.

In the first peak procedure condition (condition 2 FI 20-s PI 200-s) all birds displaying ability to time for the first 20-s as responding increased to its highest point at or near the expected time to reinforcement. During the extended part of the trials hens 8.2, 8.5 and 8.6 showed a resonance of behaviour and all birds responding increased towards the end of the session. In the second peak procedure (Condition 4 FI 40-s PI 400-s) there were similar patterns of responding those seen in Condition 2, with an increase in responding at or near the expected time to reinforcement. Birds 8.1 and 8.4's responding showed a resonances similar to that is seen in Condition 2. All birds also continued to respond throughout the expended part of the trial. Condition 6 (FI 20-s and PI 200-s no houselight) displayed similar results to the two previous conditions with the exception of a resonances pattern in responding was displayed by all birds. Thus the first three conditions appear to show that the birds were able to time during a

time period that is similar to the FI component of the sessions, but during the extended PI sessions birds showed no evidence of timing beyond that point.

In Condition 7 and 8 a houselight was introduced to examine whether the use of the houselight affected the ability to time. The use of the houselight was similar to Sanabria and Killeen, (2007) The aim was to make the trials more obvious. Condition 7 introduced a houselight for the whole duration of the session. Figure 10 shows that the inclusion of the houselight did not affect the pattern of responding and they were similar to those in previous conditions. In Condition 8 the houselight was on during the trials and off during ITI. This produced similar results to the previous condition, with a resonances pattern in the response distribution. The results of this study were similar to the results of Sanabria and Killeen (2007) who also found a resonances pattern of responding.

Discussion

Hens were studied using a peak procedure as a time perception task in which they experienced FI and PI schedules with the set durations of 20-s and 40-s. The aim of this research is to investigate the perception of time by hens. Initially the research attempted to replicate with hens, aspects of a procedure used by Kirkpatrick-Steger, et al., (1996), who used a peak procedure to investigate the timing ability of pigeons. This procedure generates a pattern of responding that approximates a normal distribution with a peak at around the time that responses are normally reinforced. Results reported by Kirkpatrick et al, showed a formation of a double peak in one of the studies, which was the primary goal of this research. During the six conditions of peak testing a double peak was not discovered, a single peak however was. This present study contributes new information on the time perception in hens. During PI trials there was an increase in response rate,

with it peaking at or just after the expected time of reinforcement before decreasing. The responding across all conditions showed that no second peak developed during the extended time period, and that responding continued for the duration of each trial. The PI trials were 10 times longer than the FI value in 5 of the conditions and 4 times longer in one. The PI trials automatically ended at the end of each trial, and this was done in order to reduce the amount of resurgence. Across all conditions and hens the responding continued and did not extinguish at any point, with resurgence patterns evident in a majority birds and conditions.

Kirkpatrick et al., (1996), was able to produce a pattern of responding which had a double peak in FI PI ratio of 1:4, which was not produced in the current study. The difference between the Kirkpatrick et al., study and the current one was firstly, the ITI was larger, 5-s compared with 2.5-s, the ratio of FI to PI was smaller for the Kirkpatrick study, the houselight was on during trials and ITI and off during reinforcement. The pretraining times were similar with both studies using 30 days. The difference however was that within the peak testing condition, the first 10 trials were FI trials only in the Kirkpatrick et al., (1996) study and the current study using a mixture of FI PI trials from the beginning of peak testing. The peak testing was also run for twice as long in the Kirkpatrick et al., (1996) paper. Some of the data Kirkpatrick et a., (1996) produced was similar to the current project with a single peak being evident during the first 25 days of the condition, and a second peak developing during days 26 to 60. The extended peak testing may have been a factor in the development of this peak.

Sanabria and Killeen (2007) have also produced similar finding with rats; there research had produced data with a single peak. Sanabria and Killeen (2007) FI pretraining was a lot shorter, with only six days used, but session comprised of

150 trials or 2 hours duration, which was overall more trials than the current study and Kirkpatrick et al. The single peak distribution has also been seen in (Cheng, Crystal & Westwood, 1993; Gatless & Kirkpatrick, 2009; Fox, Hand & Reiley, 2010; and Roberts & Boisvert, 1993).

The length of the trials across the conditions of the current study were between 20 and 30 day, the other studies using a similar condition length, producing similar patterns of distribution i.e. Crystal and Westwood, 1993; Sanabria and Killeen, 2007. However, Kirkpatrick et al,. sessions ran for twice the length where a double peak was evident. The extended peak testing may have been a contributing factor in the second peak development, however other studies within the Kirkpatrick et al., studied also showed a single peak with condition that last more than 30 days.

One weakness in the design of this project is the same 6 hens were used in all conditions. This, however, was an unavoidable constraint due to no other animals being available at the time the experiments was run. It would have been interesting to see the effect of using a houselight from the start of experiment. Second weakness was the number of conditions, it could have been beneficial to include shorter FI/PI ratio in order to examine the effect of the houselight during these conditions. This was not possible due to the time constraints of this project. Despite the same hens being used, it was clear that having the houselight on or off during the sessions had an effect on performance, and this is most obvious when performance on Condition 3 is compared with performance on Conditions 1, 4, 5 and 6 (see Table 3). Increasing the numbers of days each condition was run for could have also affected the outcome of the second peak, with an increase to 60 days opposed to 30, but due to time constrains this could not be done.

An important conclusion from these experiments is that hens do not appear to have the ability to time using the peak procedure. The present experiment tested only PI trials that 4 and 10 times longer than the FI schedule in effect. Further research around variable ends would be necessary changes in FI PI ratios and an increase in the number of days in which the conditions are run for would be useful.

Appendix A

Summary data from all six hens on FI and PI trials. Are attached on a CD

Appendix B

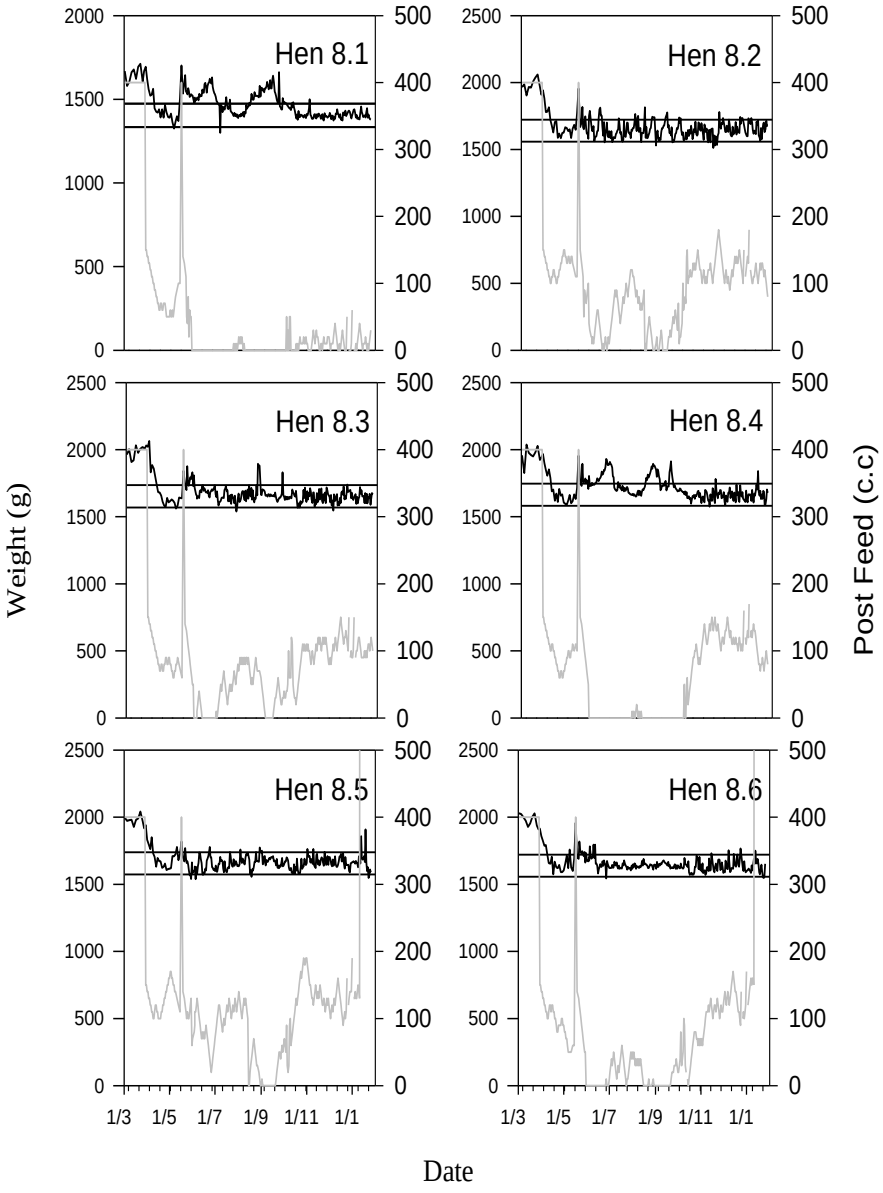
The ethics application, ethics approval with ECN number; Copy of the Med PC-IV program for running of the program are attached on a CD.

Appendix C

The event data files that were collected for all birds, across all six conditions are attached on a CD.

Appendix D

Hen weights for all six hens from free feeding to end of experimental time, including the 80% +/-5% of free feeding weight horizontal lines and post feed.



Appendix E

Excel and sigma plot files for all condition and all hens. Are attach on a CD

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